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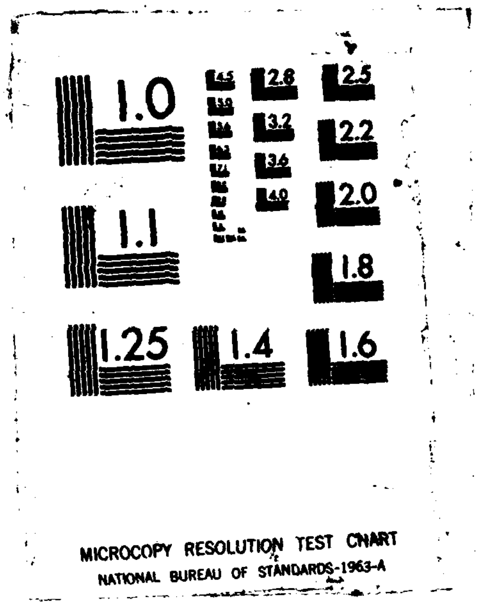
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AFWAL-TR-87-2005

HIGH VOLTAGE PULSE TEST PLAN

W. G. Dunbar

Boeing Aerospace Company
P.O. Box 3999
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April 1987

Final Report for Period 31 March 1986 - 15 December 1986

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This report has been reviewed by the Office of Public Affairs (ASD/PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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The purpose of this program is to prepare a high voltage pulse test plan for three types of test articles to interrelate the findings of the "High Voltage Pulse Test Survey" and "High Voltage Testing: Volume I, Test Program Report, and Volume II, Specifications and Test Procedures", AFWAL-TR-82-2057. This test plan will be developed from the baseline of test procedures established in Volume II which utilize a 1.2 x 50 microsecond waveform. The test plan will detail other pulse waveform parameters, voltage magnitudes, and number of pulses required to evaluate the component under test in conjunction with the results of the Pulse Test Survey already completed (AFWAL-TR-85-2079).

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FOREWORD

Presented herein is Boeing Aerospace Company's Final Report covering work accomplished on Contract F33615-81-C-2013, Task 27 for the period of 31 March 1986 through 15 December 1986. This contract is being performed for the San Jose State University Foundation, San Jose, California. The program is under the direction of Dr. J. D. Pinson, SJSUF.

W. G. Dunbar is the technical leader and B. L. Carlson is the manager of this work for The Boeing Aerospace Company. This work was sponsored within AFWAL Project 3145, Task No. 32, under the title "High Voltage Pulse Test Plan." The author would like to thank Daniel L. Schweickart of the Aero Propulsion Laboratory at Wright-Patterson AFB for his technical input and guidance during the program.

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I. PROGRAM OBJECTIVES

This pulse test plan will contain the configuration, operation and maintenance test requirements, equipment requirements, and procedures for high-voltage pulse testing of aerospace parts and equipment. The plan details peak voltage and test pulse rise time and fall time as they are applied to evaluate electrical insulation within electrical and electronic system components.

KEY WORDS

Pulse Test Set
Pulser
Test Chamber
Controls
Instrumentation
Test Articles

II. SCOPE

The major tasks reported in the high voltage pulse test plan are:

- The selection of test articles based on test data obtained for the components evaluated in contract F33615-79-C-2067.
- Test article preparation shall be called out for each specific type test article(s).
- Test parameters shall be established for each test and test sequence in conjunction with "High-Voltage Testing: Specifications and Test Procedures" (AFWAL-TR-82-2057, Volume II) and the Pulse Test Survey (AFWAL-TR-85-2079).
- Pulse characteristics shall be determined based on the component design and operating characteristics.
- Comparative test criteria shall be made for each selected component to evaluate each specific test in the test sequence.
- Test result evaluation guidelines shall be established.

III. BACKGROUND

Specifications and tests for eight components used in high voltage power equipment and systems were prepared in contract F33615-77-C-2054, "High Voltage and High Power Specifications and Tests," and reported in Air Force document AFAPL-TR-2024, "High Voltage Specifications and Tests." In this document a pulse test was specified with parameters to be determined. From 1979 through 1981 several test articles were "pulse tested" in contract F33615-79-C-2067, "High Voltage Testing." These data were reported in "High Voltage Testing," AFWAL-TR-82-2057, in five volumes entitled: Vol. I; "Test Program Report," Vol. II; "Specifications and Test Procedures," Vol. III; "Generator Test Procedure," Vol. IV; "High Voltage Design Guide: Aircraft," and Vol. V; "High Voltage Design Guide: Spacecraft." Each test article was pulse tested using an IEEE standard number 4, double exponential wave shape; that is, a 1.2 μs rise time to 90% peak voltage and a 50 μs decay to 50% peak voltage. Pulse generators used to evaluate commercial power system equipment use this waveform.

In 1984 a "Pulse Test Survey" (AFWAL-TR-85-2079) was completed on contract F33615-81-C-2013 to summarize and evaluate government, industry, and technical reports on high voltage pulse testing of commercial and experimental parts, materials, and components.

The challenge of the next decade in high power systems for aircraft and spacecraft will be to provide high power with improved system performance. Reliability, survivability, adaptability, and endurance will continue to be important in high-power system technology considerations for mission success. To meet this challenge it is necessary to include partial discharge and pulse testing to the acceptance test qualification of high power equipment. Indeed, many new technologists must be trained for the design and operation of this high powered equipment before their technologies advancement can be fully achieved. Spacecraft power requirements have increased dramatically since the first flights in the 1950's of a few watts to the multikilowatt systems of the 1970's and 80's. But increases to 25 kW will be followed closely to the 100's of kilowatts by the mid 1990's and finally the megawatts in the early part of the 21 century. Likewise, the voltage has steadily increased to higher values. By the 1990's voltages of 50 kV to 1.0 MV will be considered for high power equipment. These advancements will be met in a systematic way. Electronic and pulse power systems cannot be merely scaled for increasing power. There are many

obstacles such as natural and induced environment, weight, volume, EMI compatibility, and reliability to be considered. Electrical testing will become very important for the determination of electrical performance, acceptance, and endurance. Pulse and corona tests will be emphasized.

IV. PULSE TEST SET DESCRIPTION

The test set consists of two major components: a pulse forming network (Pulser) capable of several pulse shapes that may be configured to supply the pulse shape requirements of the test article; and a test chamber provided with interlocks which interrupts high voltage if the access door is opened or insecurely closed. The pulser has measurements of 67 inches high, 62 inches wide, and 124 inches long, and is mated to a test chamber 4 feet wide, 4 feet tall, and 9 feet long. Sensors installed in the equipment and test chamber are used to monitor signal events in real time. External instrumentation displays and stores test results for recall and examination at the end of the test period. System controls used to select the pulse parameters are interlocked into the safety system. A drawing of the test set is shown in Figure 1.

A. Physical Description

Both metal enclosures may be filled with either of two per-fluorocarbon gases, freon R12 or freon R114, atmosphere. Access to the test chamber is from the top side for purposes of installation, connection, or removal of the test article.

Since the pulser is designed for externally actuated reconfiguration, it need not be opened except for maintenance and repairs. Pressurized gases are required for operation. A nitrogen plus 2% oxygen mixture is required for the trigger, and a freon gas for the test chamber. Fiber optic lines, cables, hoses, and shielded conductors are required to connect the gas bottles, instrumentation, and control devices to the test set. A control console and instruments are required for operaton and control of the set. A block diagram of the 400 kV Marx system is shown in Figure 2.

1. Test Chamber

The test chamber is a large, sealed, rectangular cross section box with an access lid on the top to minimize loss and contamination of the insulating gas during installation of a test article. Two outputs from the pulser terminate inside the test chamber. One terminal for long pulses; the other terminal for short pulses.

2. Pulser

Several pulse shapes are available from the pulser for the testing of different electrode configurations with gas, fluid, and solid insulations applicable to high voltage electronic equipment. Assembled components limited only by the test chamber

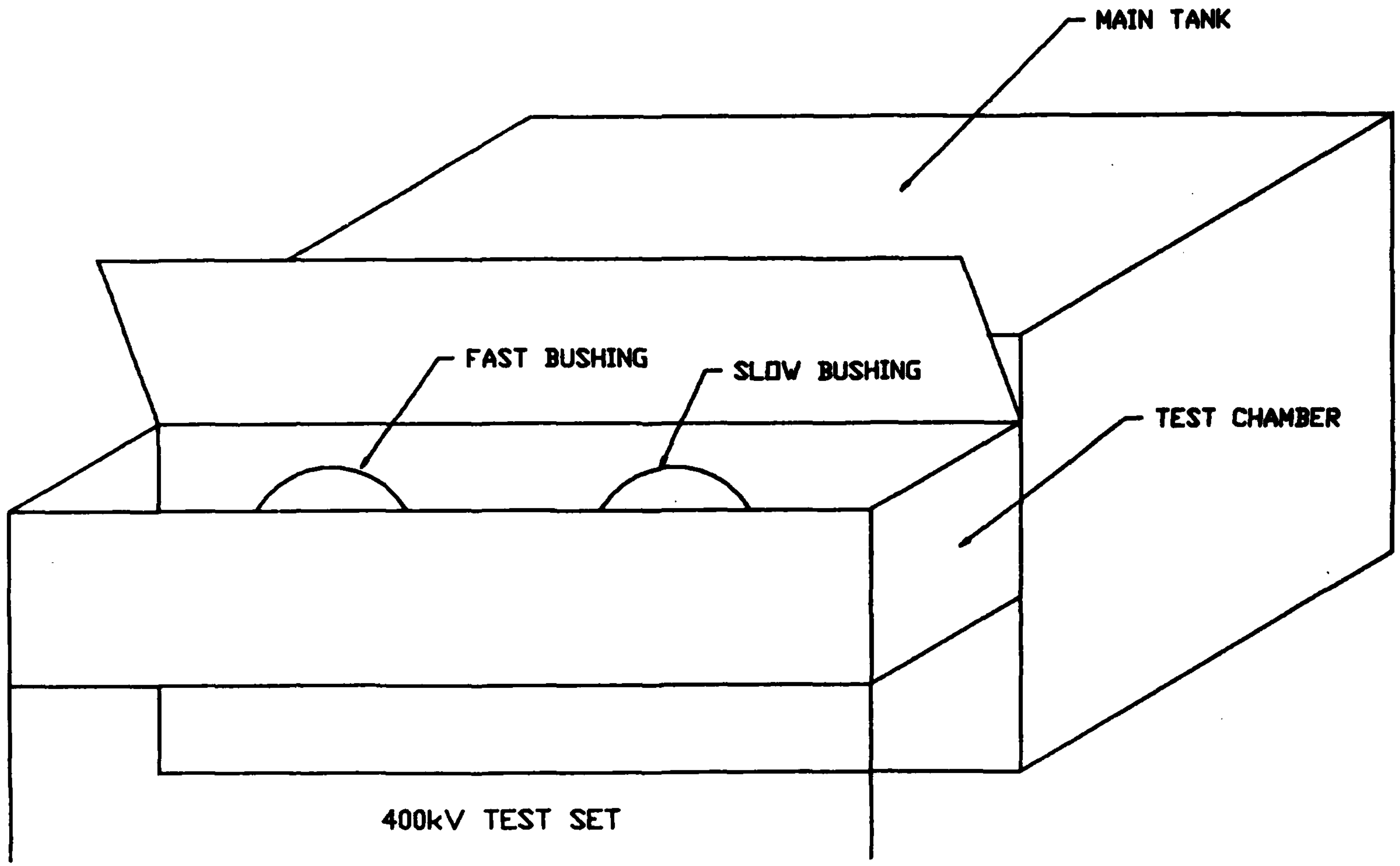


Figure 1. Pulse Test Set

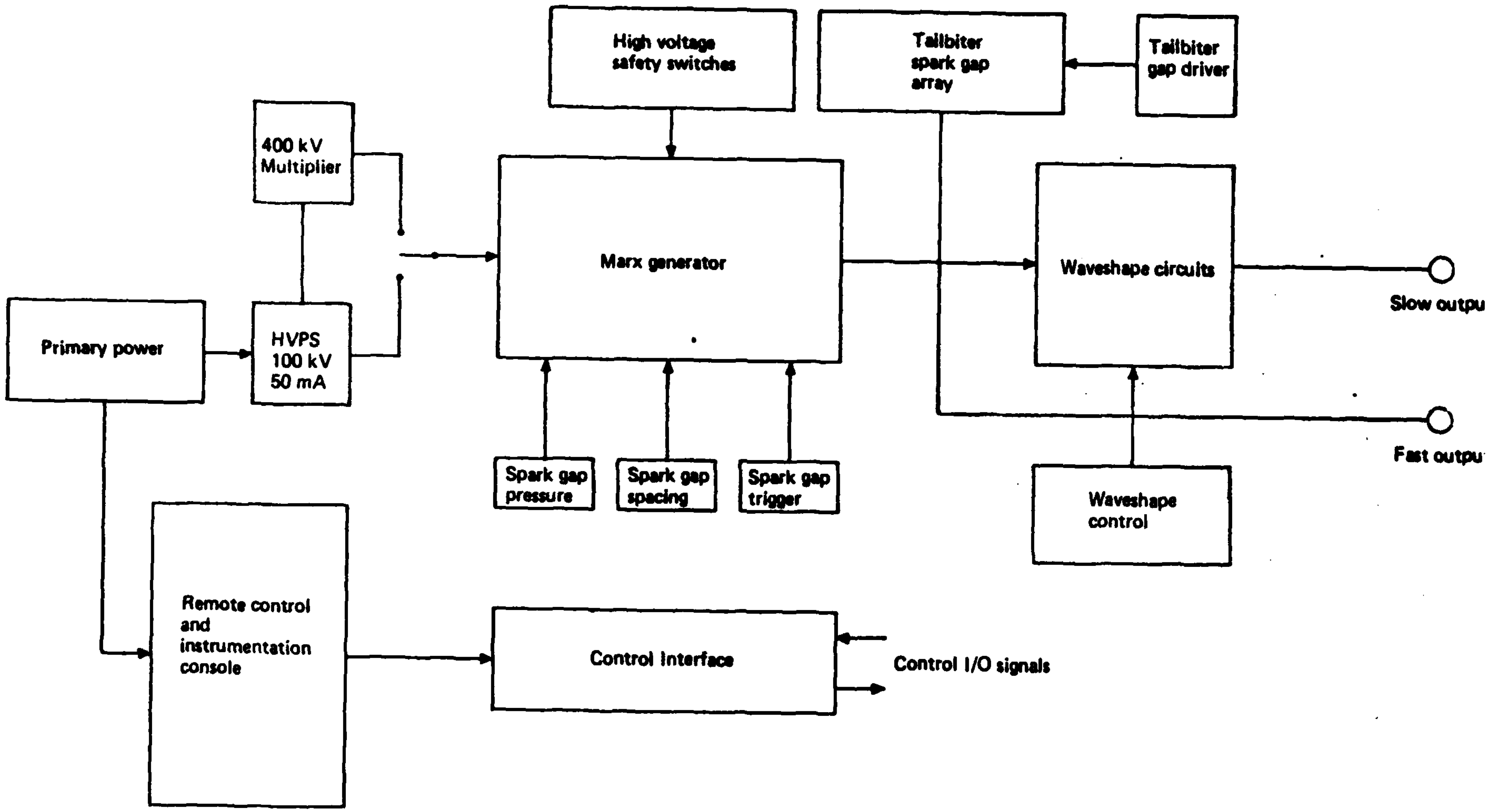


Figure 2. 400 kV Marx Test Set Block Diagram

dimension and inductance may also be tested. The pulser has the capability to generate and transmit several types pulses to the test article. Transmitted pulses may be designed to have the rise time (t_1), dwell time (t_c), and fall time (t_2), similar to the equipment to generate lightning-induced and switching pulses shown in Table 1. Electromagnetic pulses have rise times of less than one nanosecond and are considered only for shielding and induced cases and thus not simulated by this test set.

Table 1. Pulse Duration Variables

Configuration	Rise Time t_1	Dwell Time Continuously Variable t_c	Fall Time t_2
1	10 ns	*	100 ns
2	50 ns	100-300 ns	50 ns
3	250 ns	0.5-1.5 µs	250 ns
4	0.9 µs	5-20 µs	0.9 µs
5	1.2 µs	*	50 µs
6	100 µs	*	2500 µs
7	500 µs	*	2500 µs

Pulser design features include:

- o Maximum charge voltage to 500 kV pulses.
- o Capacitor dump in case of trouble.
- o Dielectric gas may be selected to meet the required dielectric properties of dielectric strength, corrosion, and toxicity; freon R12 or freon R114 is recommended.
- o Five stage Marx generator as shown in Figure 3.
- o Single point ground connection at the load.
- o The molybdenum electrodes in triggered gaps have reduced jitter but must have the macro whiskers removed during cleaning, DO NOT POLISH (see Pulse Test Set Maintenance and Operations Manual). The gaps are shown in Figure 4.
- o Positive and negative output polarity.

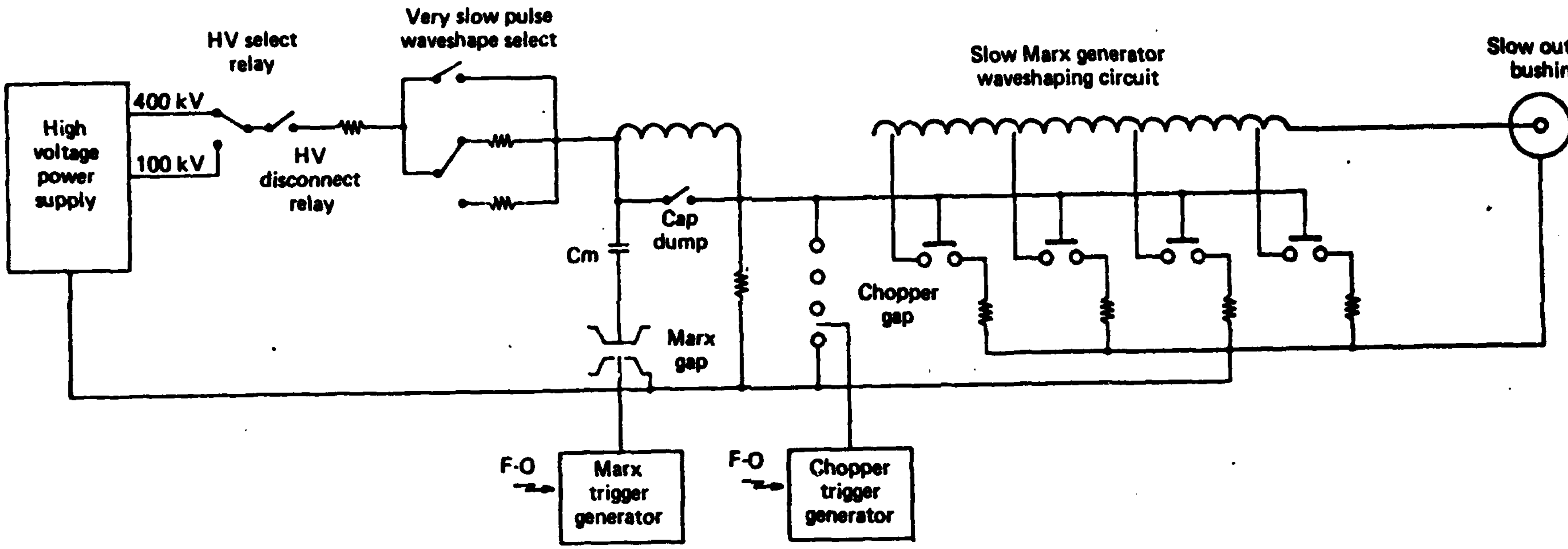
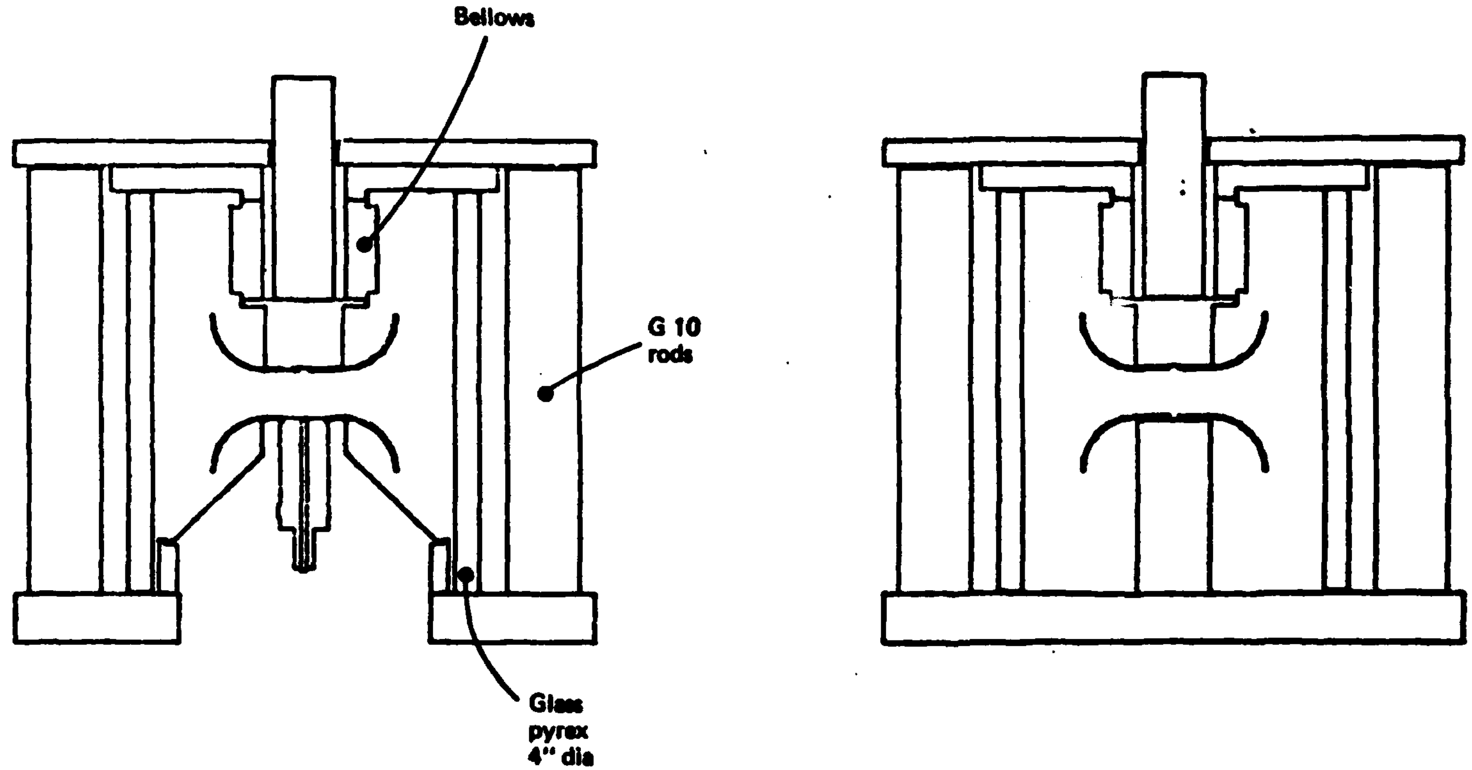


Figure 3. Marx Generator for Slow Waveshapes



Triggered Spark Gap

Over-Voltage Spark Gap

Figure 4. Gap Configurations

- Repetition Rate: two shots per minute for short pulses; less than one shot per minute for longest pulses.
- A multistage electrode gap is used for wave shaping to obtain wider operating range and reduce jitter.
- Produces full voltage to loads of 1 nanofarad or less.
- Can produce multiple wave shapes with external remote configuration control.
- Marx and wave shaping circuitry are removable from the side of the tank for easy access and maintenance.

3. Controls Indicators and Interlocks

There are four control indicator panels, as shown in Figures 5, 6, 7, and 8. The panels have the following functions:

Monitor/Startup Panel

Setup/Firing Panel

Circuit Breaker Panel

Pneumatic Control Panel

A complete description, function, and operation of each control and indicator is described in the Pulse Test Set Maintenance and Operations Manual.

a. Interlock circuit - An interlock circuit is provided to prevent simultaneous operation of the abort and the firing circuits. An auxiliary interlock input is provided to abort if opened. Other internal interlocks are built into the control sequence of the pulser and are explained in the Pulse Test Set Maintenance and Operations Manual provided. The external interlocks circuit enables the personnel warning equipment.

4. Instrumentation

All tests and measurements will be made using the pulser and its attached chamber. The signal output measurements will be made using the pulse test external signal processor computers and displays.

a. Voltage and current probes - An output current monitoring probe with an accuracy of at least ± 5 percent is provided. Its output is calibrated in volts per amperes suitable for connection to the display input. A capacitive voltage divider is used to sense the pulse leading edge of the fast pulses and a compensated resistor/capacitor divider for the slower pulses. BNC receptacles or equivalent are available for output voltage and current monitoring with high impedance (1 megohm)

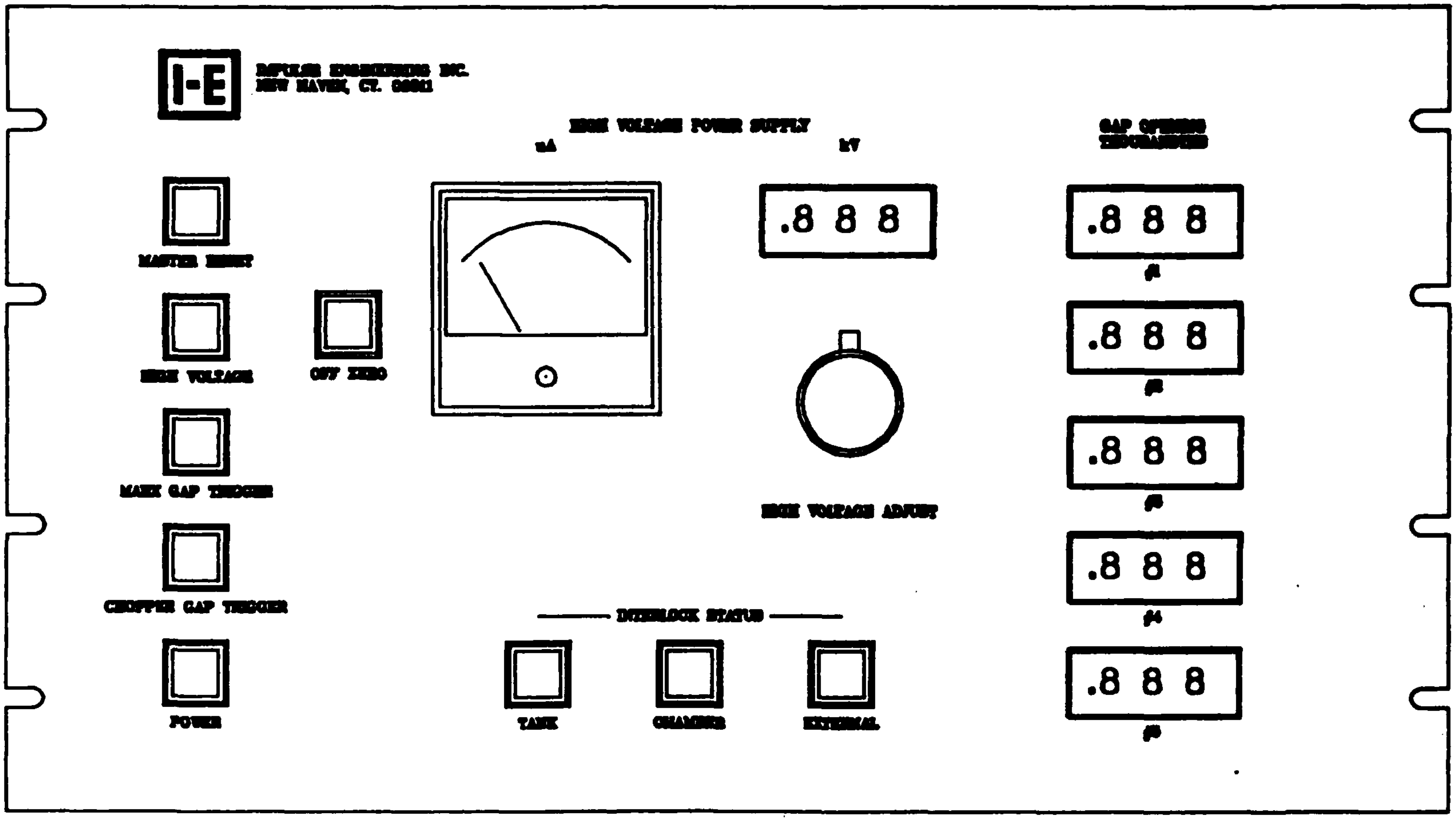


Figure 5. Monitor/Startup Panel

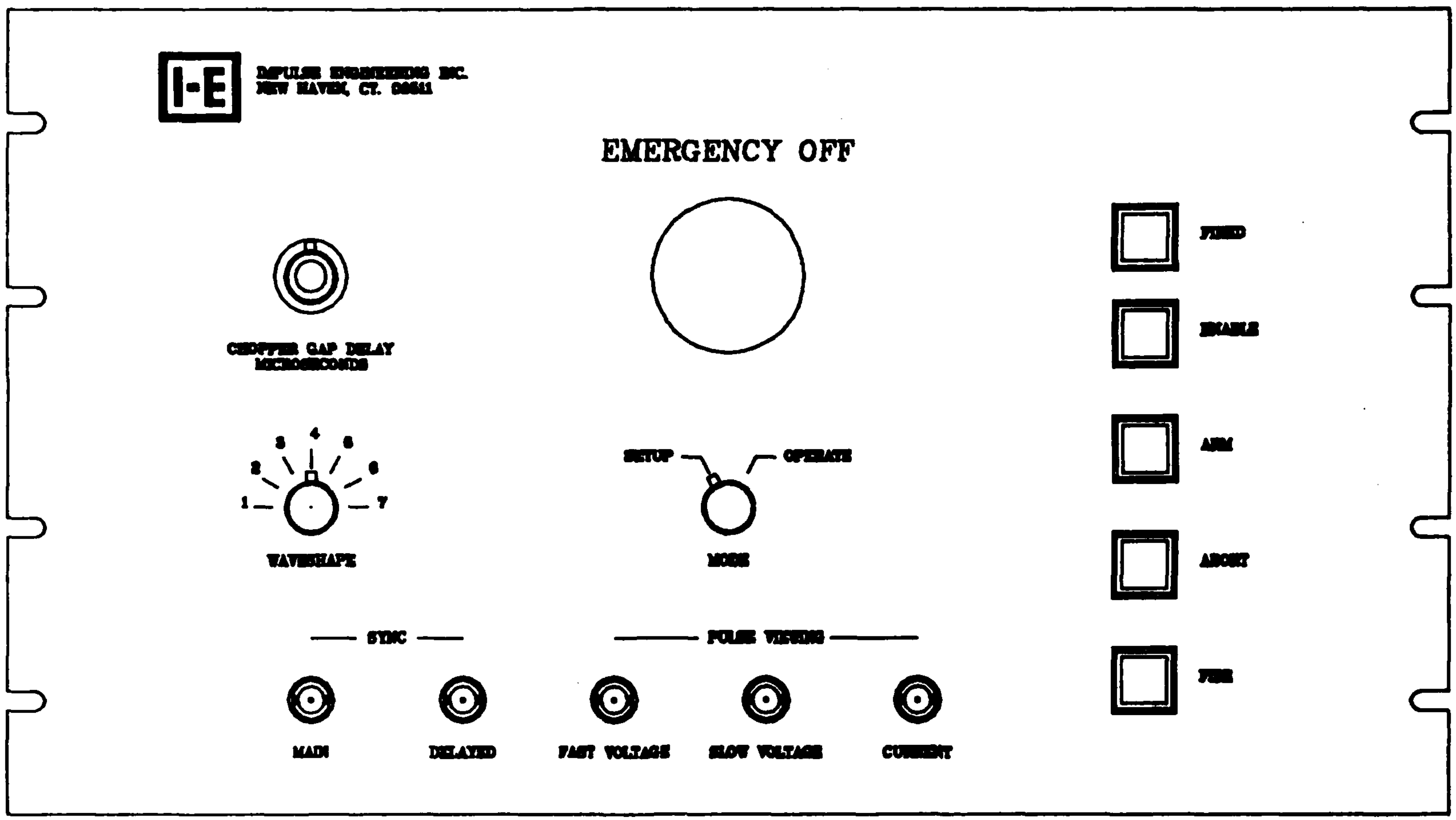


Figure 6. Setup/Firing Panel

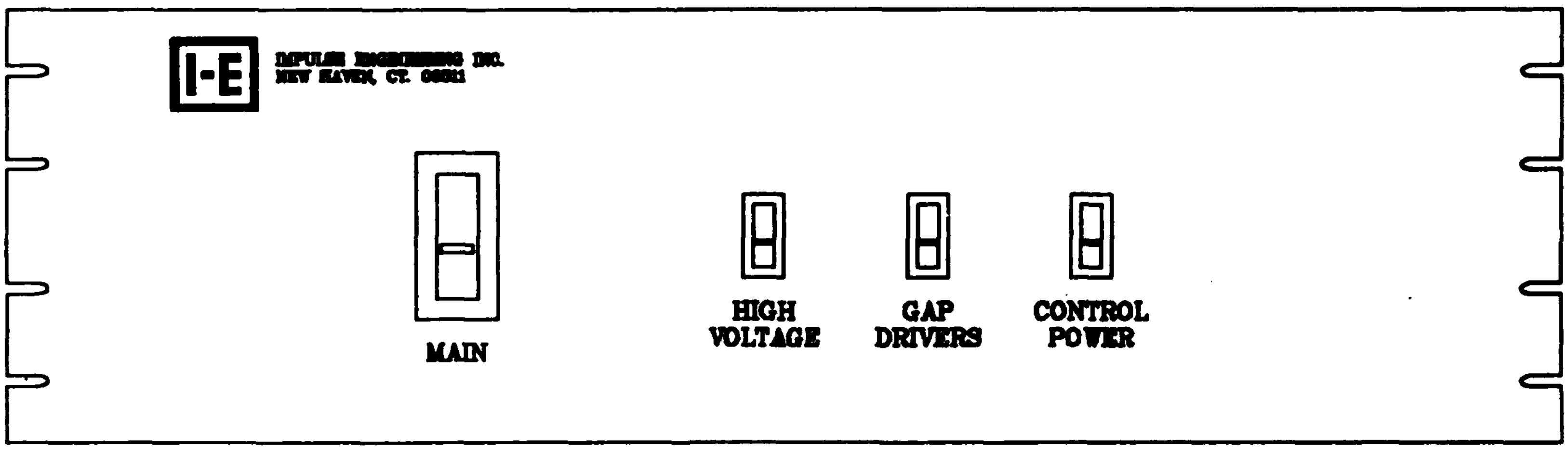


Figure 7. Circuit Breaker Panel

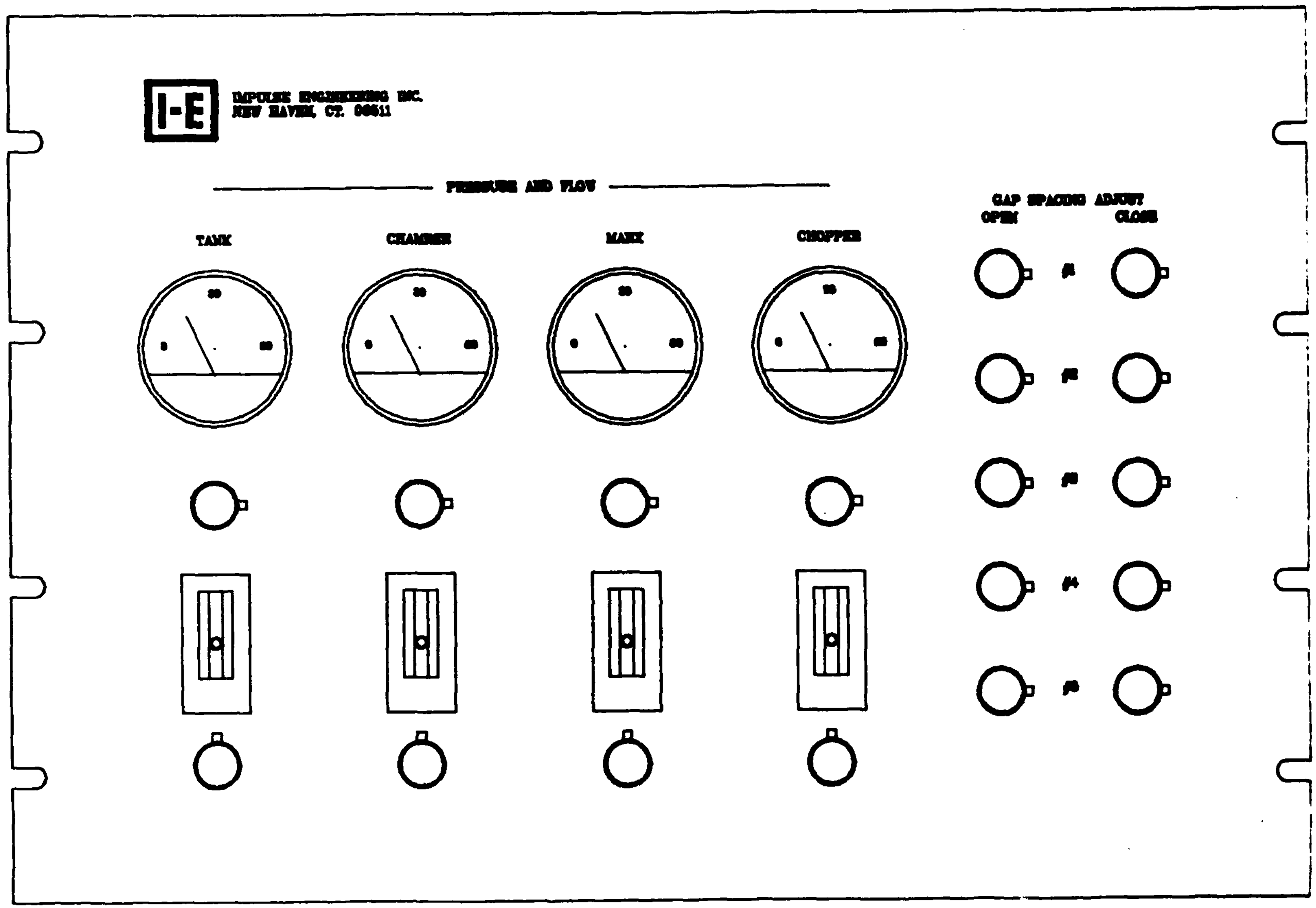


Figure 8. Pneumatic Control Panel

analog measuring test equipment. The analog voltage output signal amplitude is less than 400 volts.

b. Signal conditioning - All signal inputs are optically isolated from the high voltage, or designed with a sufficiently low impedance path to ground to protect the signal circuits.

c. Display - The output of the signal conditioning circuits are compatible with the input to a Tektronix R7633 with 7A24, 7B53A, and 7D12+M2 plugins or equivalent. The space for this equipment is integrated into the control console.

d. Pulse Test Equipment - The transfer function measurements are based on the Tektronix displays and computer enhanced data. The probe electrical characteristics will be characterized as a function of frequency to determine appropriate compensation during the transfer function measurement. The pulse tests are intended to simulate the effects of transients, short circuits, and attenuated electromagnetic pulses directly attached to the test article port. A double exponential or chopping Marx generator circuit configuration will be used to produce the waveform of the selected value. Wave shape data will be recorded with transient digitizers and/or storage oscilloscopes. The storage oscilloscope will be used primarily to monitor the pulse generator output waveform. The digitizers will be used to monitor transients induced in the test article. The induced transient data will be recorded using computer/controller for post-test processing.

V. TEST ARTICLES

Three type test articles shall be used to verify operating qualification. These test articles are to be selected utilizing the information from the "High Voltage Pulse Test Survey" and "High Voltage Testing: Specifications and Test Procedures." The tests shall be used to further develop test procedures established in the "High Voltage Testing: Test Program Report" which utilized a 1.2 x 50 microsecond waveform. This test plan details other pulse waveform parameters, voltage magnitudes, and number of pulses required to fully evaluate the test article for flaws, workmanship, and longivity in addition to the qualification verification.

A. Selection

Included in the "High Voltage Testing: Specifications and Test Procedure" were a summary of the high voltage pulse test parameters based on test results for the 14 test articles listed in Table 2. The cable assemblies, including cables and connectors were taken from unqualified stock and were not expected to meet the required test specifications. The alternator coils were small samples of coils used in a 17 kV ac generator. These coils had critical test installation parameters and were difficult to control in a non-qualified test fixture. The capacitors and transformers were pulse tested following maximum dielectric withstanding voltage and partial discharge tests.

Three test articles with different electrical characteristics are selected for test planning. Included are:

- o Magnetic Devices
- o Cables
- o Capacitors

With these type test articles, several Pulse Test Set configurations can be used to determine the test article characteristic behavior to the fast, slow, or chopped waveforms.

1. Magnetic Devices

Three type magnetic devices are considered for test: high voltage transformers, pulse transformers and inductors. Each type test article will have unique characteristics that may be determined by a pulse test. High voltage transformers can be tested for transient behavior due to short circuits and induced electromagnetic pulses.

Table 2: Pulse Test Parameters and Results

Components	Rating kV DC	Proposed Value kV	% Rated Voltage
Cable	90	180	200
Cable Assembly	90	180	200
Cable Assembly	60	120	200
Connector	60	120	200
Cable	17	34	200
Connector	17	34	200
Cable Assembly	17	34	200
Capacitor	100	175	175
	100	175	175
	80	140	175
	15	27	175
Alternator Coil Sections	2.8	5.6	200
Phase-to-Phase	29.6	60	200
Pulse Transformer Primary to Ground	20	25	125
Secondary to Ground	200	250	125
Pri-to-Sec	20	25	125

Transformers exposed to the environment in terrestrial use must also be tested for simulated lightning impulses and switching surges.

Pulse transformers must be tested for short circuits and fast pulses in addition to their specified output wave shapes. High voltage power frequency transformers must be tested for lightning-like pulses and short circuit transients.

The pulse test waveforms that should be applied to the three types magnetic devices are shown in Table 3. Peak voltage magnitudes for the magnetic devices will be as listed in Table 2 for pulse transformers, that is 125% rated peak voltage. Peak magnitude test voltages for inductors and power transformers shall be more like that of an alternator coil, typically 200% rated peak voltage.

The number pulses may be varied to accomodate the test director's requirements. It is necessary to obtain enough points for a minimum statistical group of 12 or more. The minimum number pulses shown in Table 3 satisfies that requirement.

Table 3: Test Article Pulse Test Waveforms

Test Article Type	Applied Waveforms (see Table 1)	Polarity	Number Pulses (Each Waveform) Peak Rated Voltage					
			50%	100%	125%	150%	175%	200%
Power Transformers	1, 4, 6	+ & -	3	5	5	5	3	3
Pulse Transformers	1, 3, 5	+ & -	4	5	5	-	-	-
Inductors	1, 4, 6	+ & -	3	5	5	5	3	3
Cables	1, 2, 4, 5, 7	+ & -	3	5	5	5	3	3
Filter Capacitors	2, 4, 5, 7	polarized	3	5	5	5	5	-
Pulse Capacitors	1, 2, 3, 5	polarized	3	5	5	5	5	-

2. Cables

There are two types cables shielded and unshielded. In addition, there are cables with and without semiconducting layers over the conductors and under the braids. It is the purpose of the pulse test to determine the integrity of the insulation system with respect to the joints at the connectors and flaws within the insulation dielectric system. Cables, like power transformers, may be subjected to pulse voltages rated to 200% rated peak voltage without damage to a homogeneous insulation system as shown in Table 3.

When possible, cables should have connectors on each end with the connector plugs mated into known receptacles that will withstand at least 50% higher test voltage than that to which the cable will be subjected.

3. Capacitors

Capacitors are designed to operate with either very fast discharge (low inductance) as in pulse forming network or as a energy smoothing device as in a filter. High voltage capacitors of both types, without respect to weight and volume, may be obtained from Axel, Hafely, General Electric, Aerovox, High Energy Inc., and Maxwell.

Filter capacitors may be subjected to transients, lightning, and short circuits. Pulse forming network capacitors will be subjected to fast discharges plus lightning, and transients. All capacitors at some time may be subjected to a limited number chopped discharges. Capacitors may be pulse tested to the waveforms shown in Table 3.

4. Component Characteristics

Low inductance capacitors should be used for initial tests to demonstrate the nanosecond pulse rise times. Filter capacitors for electromagnetic pulse attenuation are low inductance capacitors as are fast discharge capacitors.

Alternating current filter capacitors and dc ripple filter capacitors have high inductance and should be tested with the slower pulse rise times.

Cables may be tested with all type waveforms, fast and slow. Impedance termination to match to the cable characteristic impedance is important. That is, the cable should be energized on one end with the other end terminated.

Inductors are easily ruined if improperly tested. The pulse test should not be induced across the secondary (high-voltage) winding. When tested with that configuration the majority of the pulse voltage is imposed across the first 10% to 25% of the winding due to its high impedance. This may destroy the winding. The pulse can be induced into the primary winding without harm to the transformer.

Pulse test connections for transformers should be:

- o Between primary and secondary and other primaries
- o Between each secondary and all other secondaries
- o Between each winding and frame
- o When possible, excite the primary and measure the secondary outputs.

For inductors, the connection should be between winding(s) and case or ground.

5. Suggested Test Articles

Suggested suppliers of test articles are listed in Table 4. All test articles have voltage rating not to exceed 200 kV. Test articles need not be military qualified hardware. However, attention should be paid to selection of hardware which is representative of lightweight, high energy density, small volume designs.

B. Preparation

Before installing a test article in the test chamber it must be inspected for cleanliness, protrusions, sharp edges, disconnected shorting bars, and that the unit has properly passed all initial tests and inspections. Freon is an acceptable cleaning fluid. Water and alcohol are unacceptable. Traces of both will react with the pressurizing gas in the test chamber and become cause for premature failure or explosions.

C. Connections

The test article should be connected to the appropriate pulse test set bushing using 0.75 inch diameter copper tubing or RG219 without the braid. Only large radius (greater than six inches) bends shall be used between the test set bushing and the test article. Each test article requires its own special test connections. The connection starts by placing the test article inside the test chamber. The test article must be centrally located with as short distance as possible between the pulser high-voltage connection and test article high-voltage connection. Once in place ground connections shall be made between the test article and the common point ground. There is only

Table 4: Suggested Test Articles

Component	Manufacturer	Model/Type
Magnetic Devices		
Pulse Transformers	Westinghouse (Baltimore)	Radar
	Raytheon	Radar
	Aydin	Pulse Forming Network
Power Transformers	Westinghouse	Radar
	Rockwell Int'l. (Collins)	Transmitters
	Hadley	High Voltage, Low Power
Inductors	Westinghouse (Baltimore)	Radar
	TRW	Radar, Pulse
	Hughes Aircraft	Radar, Pulse
Cables		RG-219
		RG-8
	Rowe	Radar
	Dielectric Sciences	Radar
Capacitors*		
Pulse	Maxwell	Plastic Case
	Hughes	Metal Case
	ERIE (Murata)	Barium Titanate
	High Energy Corporation	Plastic Case
Filter	Hafely	Metal Case
	General Electric	Metal Case
	Aerovax	Metal Case

*Capacitor ratings should not exceed 0.002 Mfd.

one H.V. pulser return connection to the test chamber common point ground. The test leads must be kept short. Lead wires have approximately 20 nanohenry inductance per inch length. The test article may have one or more ground connections. If the test article is externally located there will be considerable peak voltage degradation. This leads to inaccurate and undesirable test results.

1. Magnetic Devices - Active test grounds on the test article shall be grounded to the test chamber common point electrical ground. All untested windings or metallic surfaces may be connected to test chamber ground.

High voltage may be applied to the primary winding for active tests. An active test is to energize the primary and measure the secondary output. The active pulse test evaluates the complete device. That is intrawinding and interwinding insulation systems.

The intrawinding insulation is tested by connecting all leads of one winding to the high-voltage terminal and all other winding leads, shields, case, and core to the common point test chamber ground. This only tests the insulation between adjacent windings, shields, and case, not the turn to turn insulation within the windings.

Unless the secondary as well as the primary is designed for pulse voltage input, a pulse should not be impressed across the winding. In many designs, the inductance is so great that the majority of the pulse voltage will be impressed across approximately 25% of the winding turns next to the high-voltage terminal.

2. Cables - The connector, shell, or braid shall be bonded to the chamber single point ground via the ground strap. The cable's high-voltage terminal shall be terminated at the pulse high-voltage output. A preferred test setup is to have the cable connected to the high-voltage terminal and a mating high-voltage connector on opposite end. This mating connector shall be terminated with the cable characteristic impedance. Long cables may be coiled within the test chamber.

3. Capacitors - Capacitors can have a ground connection between the metal case and/or the chamber ground terminal. The ground strap connections shall be well bonded to the test article and the chamber single point ground. Bond resistance between the test article and single point ground should be less than 50 milliohms.

D. Test Preparation

1. Inspect the test articles for cleanliness, secure connections, and correct orientation. Interconnections between the pulse test set output busing and test article input terminal must be kept short.
2. Ascertain the test article is connected to the correct pulse test set output bushing.
3. Close the lid on the test chamber and Marx generator.
4. Pressurize the test article per the Pulse Test Set Operation and Maintenance Manual specification and procedure.
5. Be sure the pulse test set output polarity is correct.
6. Prepare for test.

VI. TEST PROCEDURE

The test procedure will be used to evaluate the acceptability of the test article. Acceptability of the test article will be assessed by partial discharge, dielectric withstanding voltage, and pulse magnitude verification tests. This criteria can be used to determine the suitability of the specified test in the high-voltage specification and test procedures.

A. Test Article Preparation

The test article shall be cleaned using freon or equivalent solutions to remove dirt, greases, and salts from the terminals, insulating boards, connections, and all insulated surfaces. Sharp edges and corners shall be eliminated by adding corona shields and rounded connections. Water and alcohol products shall not be used due to their degradation of the test chamber pressurizing gas. After the test article is cleaned it must be dried and inspected for surface scaring, termination corrosion, cracks and flaws. Following each test in the test evaluation sequence, the test article must be inspected again for cleanliness, scars, marks and degradation. Any signs of arcing, burning, or swelling are cause to discontinue testing. A resume for the test preparation follows:

Select the test article
Record all test article nomenclature
Clean the test article
Inspect the test article
Be certain the test article has passed all preliminary tests delineated in the test sequence
Remove all shorting wires or bars
Install the test article in the test fixture.

B. Test Sequence

The test sequence, at minimum, includes the following operations and tests:

Visual inspection
Dielectric withstanding voltage
Partial discharge
Inspection

Pulse test

Inspection

Partial discharge.

These tests should be performed in the listed sequence. Parameters for the dielectric withstanding voltage and partial discharge tests can be found in "High Voltage Testing; Specifications and Test Procedures" for each component type. Data from the test and inspection sequence must be a part of the test report. Following each test the shorting bars or wires must be reconnected between the test terminals.

C. Installation

Before the test article is installed in the test chamber, the pulse test set configuration must be determined. The configuration is determined by the pulse parameters as defined in the Pulse Test Set Operations and Maintenance Manual. The following steps should be followed when installing the test article.

1. Inspect the test article and pulse test set configuration circuitry to ensure they satisfy the configuration requirements listed for the appropriate test conditions.
2. Disconnect the shorting bar or wire.
3. Place the test article in the test chamber. The high voltage terminal must be as close as possible to the selected high voltage output bushing.
4. Connect the ground strap to the negative terminal(s) and case and core as appropriate.
5. Connect a high voltage lead between the test article high voltage terminal and the selected test set high voltage bushing.
6. Inspect all connections.
7. Inspect the test chamber is debris-free.
8. Close the test chamber.
9. Pressurize.
10. Set up the measuring and recording equipment system as delineated in the Pulse Test Set Operations and Maintenance Manual; allow a ten minute warm up.

D. Pulse Test Set Checkout

A checkout test must be made to assure the test operator all instrumentation parameters have adequate margins for the test. The checkout test should be made at approximately 50% of the initial test voltage level to prevent damage to the test

article. Procedural steps that must be taken before the test can be made are listed below.

1. Pre-Operating Inspection

Inspection is performed by the test operator immediately before testing.

- o Note signs of damage, presence of foreign objects, stray wires and cables. The test area is not to be used for storage, especially of combustible materials.
- o Check integrity of test area and test chamber. The test chamber must not be penetrated by extraneous wires.
- o Visually check connections at termination and ground. Check instrumentation coax, attenuators, connections, scopes and cameras.
- o Verify fire extinguisher is available and in certification.
- o Verify entrance door to high voltage area is closed.
- o Check certification expiration dates on instrumentation.

2. Checkout Tests

The following tests are required before test article testing commences.

1. For voltage measurements, attach the reference load in place of the test article to measure the voltage across the load.
2. Measure the reference current and record the response.
3. Confirm that the reference transfer functions are above the noise and have not overloaded the probes, fiber optics, or instrumentation.
4. Repeat the transfer function measurement with the voltage test probe terminals open circuited and not attached to test article for measurements less than 100 kV.
5. Adjust all instrumentation for the test.
6. Record test information.

E. Pulse Test Procedure

Set up the pulse generator equipment. The pulse generator maintenance and safety plan are described in the Maintenance and Operations Manual. Refer to this document prior to test for emergency procedures. The following procedure will be followed for normal pulse generator operation.

1. Clear area of unauthorized persons and unnecessary equipment.
2. Visually check system grounds, pulse generator gas and gas presssures, and high voltage power supplies.
3. Perform pretest safety procedure.
4. Select the correct test configuration for the waveform selected. Refer to the Maintenance and Operations Manual.
5. Select the test polarity, positive or negative.
6. Assure all interlocks are operating and closed.
7. Check that all operators and observers are outside the controlled high-voltage area. Close control room outer door.
8. Set triggers on digitizers and oscilliscopes.
9. Follow the pulse test set procedure for arming and firing the pulser.
10. Verify that pulse generator discharged. If there was evidence of an abnormal condition, perform emergency safety procedure per the Pulse Test Set Operations and Maintenance Manual.
11. Shut off power to main power supply after the test sequence is completed.
12. Pulse generator operator should log data after each pulse.
13. Perform post-test safety procedure as outlined in the Maintenance and Operations Manual.
14. Record responses from digitizers and oscilloscopes.
15. Prior to disconnecting the test article the ground stick must be connected to the high-voltage output bushing in the text chamber.

VII. DATA RECORDING AND HANDLING

A. Data Recording

Data taken during function measurements will be recorded as hard copy plots, digital data files, or photographs. These data records will list the following information as a minimum along with the transfer functions.

a. Date

b. Pulse number

c. Test article identification

d. Time scale

e. Amplitude scale

f. Test probe identification

g. Measurement type

h. Test configuration.

Additional information about test equipment configuration will be recorded in the test log as necessary. The closed loop system calibration transfer functions will be recorded for each test equipment configuration. The noise response transfer functions will be recorded for each test equipment configuration.

B. Data Log

The assigned test engineer will prepare and maintain a measurement log for the pulse tests. This log will include a detailed description of the test equipment and configurations for each measurement. Properly annotated calibration and measurement data plots will be included for on-site evaluation. Photos of the test equipment and test points will be included as necessary. The measurement log entries will show the time, measurement number, and test point identification to properly correlate with the recorded data.

The assigned pulse generator operator will maintain a shot log for the pulse generators. The shot log will include the shot number, charge voltage, and generator conditions as required.

C. Evaluation Criteria

Test article evaluation is determined after the test article has passed the test sequence described in Section VIB of this document which includes a final partial

discharge test. A quantitative criteria for the specific component types and voltage ratings is included in "High Voltage Testing: Specifications and Test Procedures."

No visible deterioration of the test article shall have taken place. No swelling, arcing, or tracking over the surface of the test article.

VIII. CONCLUSIONS AND RECOMMENDATIONS

A modification of the "High Voltage Testing: Specifications and Test Procedures" (AFWAL-TR-82-2057, Volume II) will be determined by various test articles performances to several pulse configurations and magnitudes. The following recommendations to the tests are presented.

- o Test a few specific type test articles.
- o Test each test article with several pulse configurations.
- o Statistical data should be used to analyze the test article characteristic response to the pulse configurations with respect to pulse rise time, pulse width, pulse decay time, pulse magnitude, and number pulses to determine life aspects.

Selected test articles should be tested to failure to establish testing limits. Some test articles should be tested with intermittent visual, partial discharge, and X-ray examinations to establish failure mechanism initiation.

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